Flexible Dimethyl ether production from biomass gasification with sorption enhanced processes

Newsletter #5 – June 2020

Project at glance

OBJECTIVE

FLEDGED project aims to develop a highly intensified and flexible process for DME production from biomass gasification.

WHY DME

DME is recognized as one of the most promising future biofuels, due to the easy adaptability of diesel engines and reduced life-cycle environmental impact.

OUTCOME

FLEDGED project will demonstrate at TRL5 sorption-enhanced gasification and sorption-enhanced DME synthesis and will assess the flexibility of the complete FLEDGED plant concept in:

i) the conversion of different feedstocks
ii) the integration with electrolyzers for power-to-DME
iii) bio-CCS leading to a negative emission system.

Where to find us

www.fledged.eu

Contact details
info@fledged.eu

FOLLOW US

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Fledged H2020 Project

Workshop on FLEDGED project results at virtual EUBCE conference: *Waiting for you!!*

Draft agenda and more information in the next page and on www.fledged.eu.

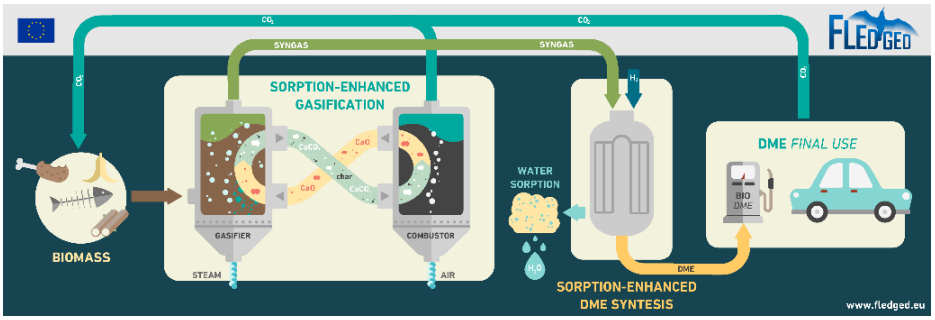
PROJECT NEWS

FLEDGED activities on biomass gasification are completed and many interesting results are available …

- **Final experimental results on SEG process experiments** in BFB at CSIC-ICB and in the University of Stuttgart pilot facility, for both stationary and flexible operation. Gasification performance assessed using wood pellet, grape seeds, straw and Econward treated waste. Successful tests involved steam-to-carbon, temperature and solid inventory influence evalutation.
- The optimal catalyst-sorbent mixture has been selected for **SEDMES testing** and catalyst deactivation mitigation strategies developed. Preliminary tests in the TRL4 facility exhibit good conversion and regeneration performance.
- Large scale **SEG simulation** with calibrated 3D models to improve performance through optimized design.

… but the project is getting on with:

- TRL5 experimental testing of the **complete SEDMES operating cycle**. 2-dimensional simulation of the reactor for tubes design and optimization of the reactor design, in parallel with SEDMES cycle design and optimization.
- Plant operating conditions, optimal design criteria and process integration on the basis of the two operating points (with and without hydrogen addition) by **techno-economic analysis** and mathematical optimization of heat recovery network.
- **Socio-economic analysis** including social and economic impact of FLEDGED technology, air quality and health impact modelling. Integration with **Life Cycle Assessment** results.
- **Risk analysis** of the different configurations of FLEGDED process by means of hazards evaluation and materials characterization.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 727600.

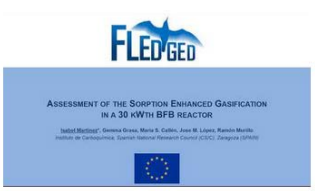
FLEDGED Webinar at eEUBCE

A **live discussion of FLEDGED activities and results** will be held during a dedicated workshop at the eEUBCE conference on 9th July, 2020 at 14:00.

The event program in brief is:

1. Pilot scale experimental campaigns in dual circulating fluidized beds	***2. Sorption-Enhanced cyclic process development and testing at industrially relevant scale***
3. Integrated process techno-economic evaluation and flexible Power-to-DME operation mode	***4. An example of circular economy: municipal waste collection, recycling process and DME synthesis integration***

If you cannot participate or if you want more details about all FLEDGED activities, project partners prepared other short presentations for you:



Have a look on www.fledged.eu !!!

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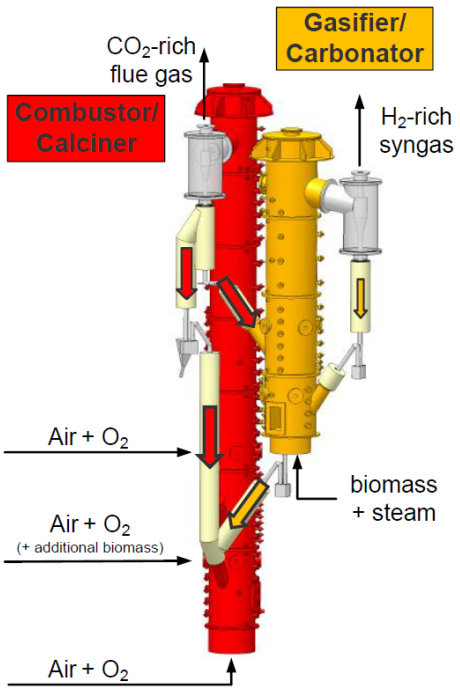
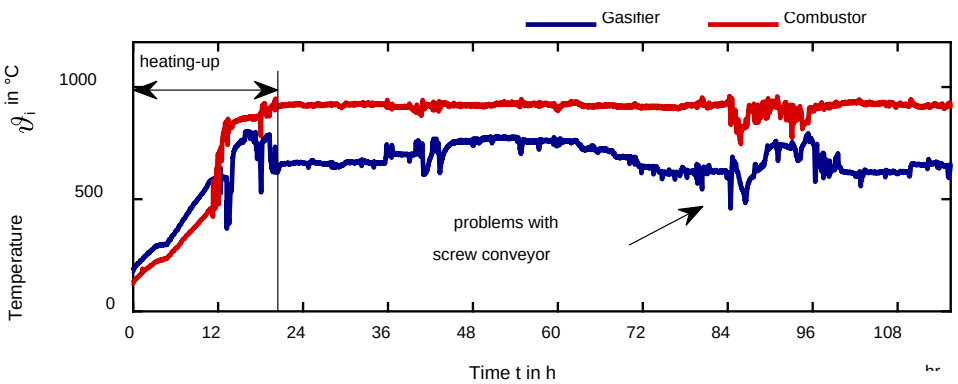
Final experimental results on SEG process experiments at pilot scale for stationary and flexible operating regimes

Tests of the sorption enhanced gasification (SEG) process in the 200 kW_{th} dual fluidized bed pilot plant at USTUTT for stationary and flexible operating regimes are completed. Experiments were conducted using two different biomasses. Wood pellets that served as reference biomass and pellets produced out of the organic part of municipal solid waste by Econward (ECO pellets). The main differences between those two biomasses are the much higher ash content of the ECO pellets (21 – 33 $wt\%_{db}$) compared to wood pellets (0.2 $wt\%_{db}$). The ash content of the ECO pellets could be decreased with each batch by optimization of the production process of Econward. Also the content of nitrogen, sulfur and chlorine in the ECO pellets is much higher than in wood pellets.



200 kW_{th} dual fluidized bed facility at University of Stuttgart

Five experimental campaigns have been conducted in total for investigating the influence of several parameters (e.g. gasification temperature, steam-to-carbon ratio, weight hourly space velocity) on the syngas composition and the process stability. The duration of each campaign was up to 120 h, including heat-up of the reactors, which lasts about 22 – 24 h. During the campaigns, the facility has been operated 24/7 in a 3 shift mode with 5 persons per shift.



Trends of gasification and combustion temperature for an exemplary SEG campaign

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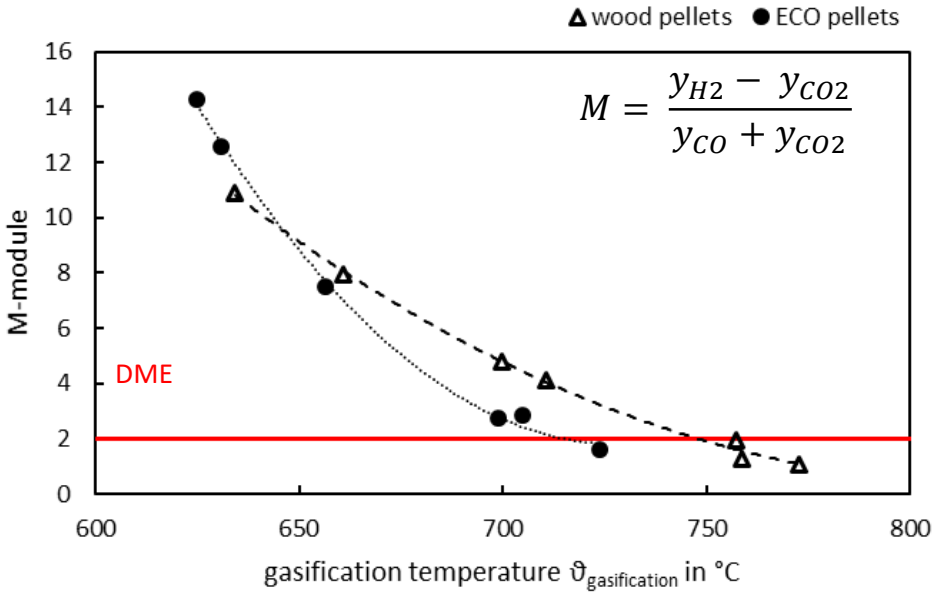
Final experimental results on SEG process experiments at pilot scale for stationary and flexible operating regimes

It could be demonstrated that the SEG process can be operated stably over a long period, which can be seen in the diagram above. In this diagram, the temperature trends in the gasifier and the combustor are presented for an exemplary SEG campaign. As can be seen, the combustor temperature has been more or less constant during the whole campaign after heating up the reactors. Only during one period, the temperature fluctuated due to problems with the screw conveyor. The gasifier temperature has been adjusted according to the experimental matrix.



M- modul vs. gasification temperature for SEG with wood pellets and ECO pellets

The gasification temperature has a huge influence on the syngas composition, as it influences the biomass conversion as well as the amount of CO_2 that can be captured by the bed material. Therefore the syngas composition can be adjusted flexibly by variation of the gasification temperature, which can be seen in the diagram on the left. For the synthesis of Dimethyl Ether, a syngas composition resulting in a module M of 2 is required. According to the experiments that were conducted, this composition can be achieved at about 715 °C for SEG with ECO pellets and at about 745 °C for SEG with wood pellets.

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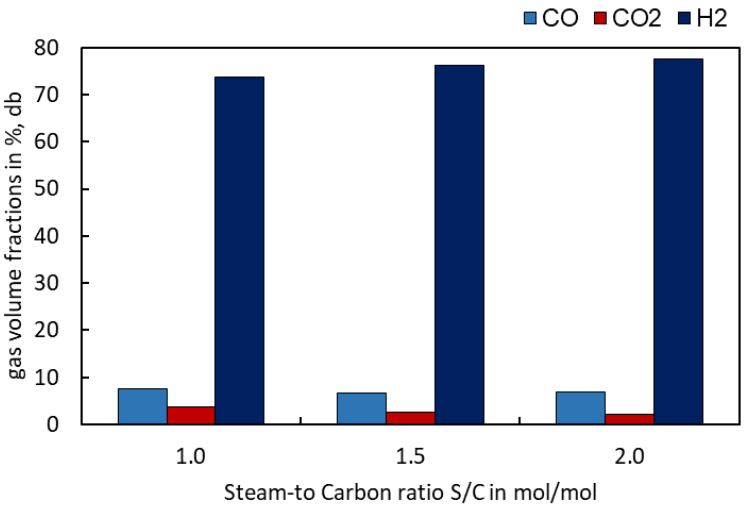
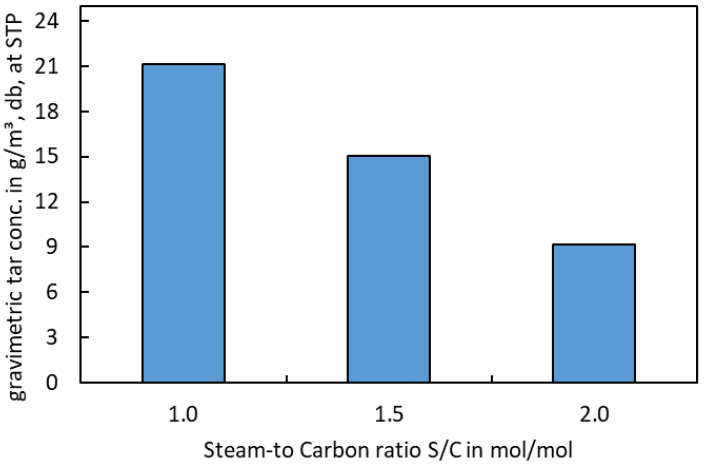
Final experimental results on SEG process experiments at pilot scale for stationary and flexible operating regimes

At temperatures higher than that, M modules <1 were achieved, giving the opportunity for including an electrolysis unit into the process chain and to add electrolysis hydrogen in times with a surplus of renewable energy.
Another parameter that has been investigated is the steam to carbon ratio. Results from experiments with wood pellets at a gasification temperature of 660 °C are presented in the two diagrams at the bottom of the page. Increasing the S/C ratio led to higher H_2 and lower CO and CO_2 volume fractions. It has been demonstrated, that the S/C ratio has a significant influence on the gravimetric tar concentration, leading to less tar in the syngas when the S/C ratio is increased.



H_2, CO and CO_2 gas volume fractions for SEG with wood pellets at 660 °C for different S/C ratios

Gravimetric tar concentrations for SEG with wood pellets at 660°C and different S/C ratios



The abovementioned results are extensively described in the public deliverable of the project, available on the website.

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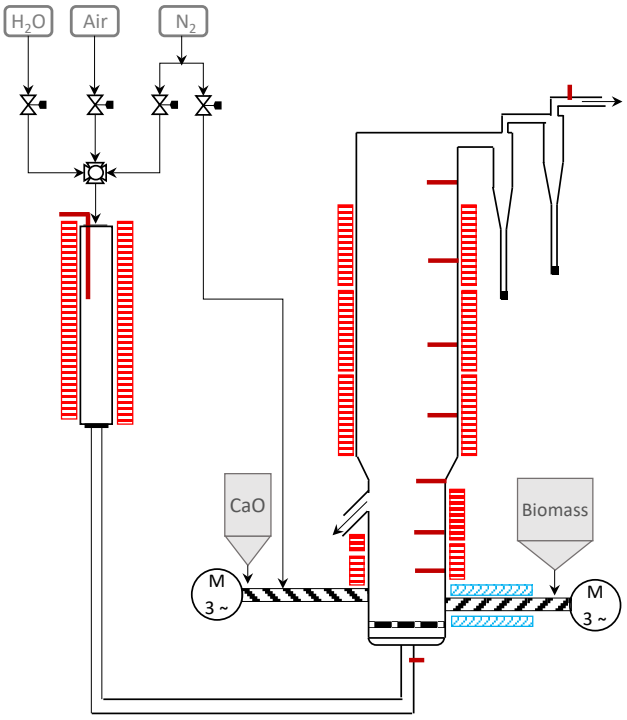

Experiments at the ICB-CSIC 30 kW_{th} bubbling fluidized bed gasifier using wood pellets,

In the 30 kWth BFB facility at ICB-CSIC, the evaluation of the Sorption Enhanced Gasification (SEG) performance has been undertaken using 6 different biomasses as feedstocks. Concretely, it has been studied the influence that the gasification temperature, the steam-to-biomass ratio and the sorbent-to-biomass ratio had on the syngas yield and syngas composition as well as in solids conversion and tar production and composition.

30 kW_{th} bubbling fluidised bed facility at ICB-CSIC.

The overall objective of the experiments performed has been evaluating the influence of each operating variable mentioned independently, as well as analyzing the effect of the biomass used in the SEG performance.

Gasification temperature had a great impact on the gas yield through char conversion, making the gas yield to increase as the gasification temperature increases. Gasification temperature was also the main variable affecting syngas composition, even if the individual effect on each gas compound was not the same. Light hydrocarbons (CH_4, C_2H_6, C_2H_4, C_2+) and tars increased noticeably when reducing the gasifier temperature, making the conditioning steps needed before the subsequent synthesis process. However, H_2, CO and CO_2 behave in the opposite way, increasing their production when gasification temperature was raised.

Differences in the total gas yield were also found depending on the type of biomass used due to the different volatile content.

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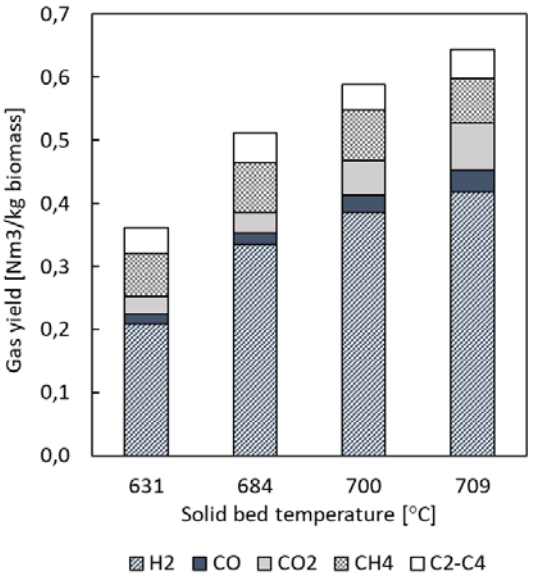
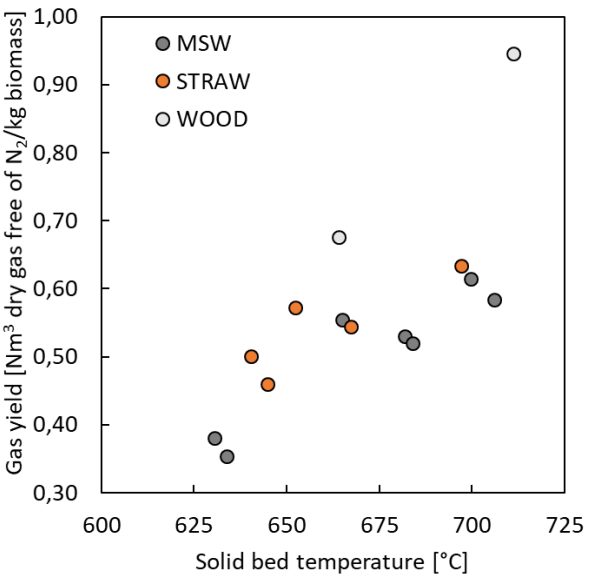
No significant effect of the steam-to-biomass ratio was found in the content of H_2, CO, CO_2 and CH_4 in the syngas when keeping the temperature and the sorbent-to-biomass ratio constant. When increasing the steam excess used, the content of C4 hydrocarbons in the syngas diminished since the reforming reactions were in this way favored, increasing the content of C_3H_6, C_3H_8, C_2H_4 and C_2H_6.

The sorbent-to-biomass ratio influenced mainly the C3-C4 hydrocarbons content and the tar yield (due to the catalytic effect of CaO towards tar cracking). Moreover, the sorbent excess used influenced the M-module reached in the syngas (i.e. the $(H_2-CO_2)/(CO+CO_2)$ proportion) since its variation affects the amount of CO_2 separated and the solid residence time of char particles, and therefore their conversion. Increasing too much the sorbent excess introduced reduces significantly the solid residence time of char particles in the gasifier and their conversion, which could limit the M-module fulfilled.





All the results obtained at the ICB-CSIC facility have been included in the public deliverable 2.5 available in the dedicated section of the website, as well as in the scientific paper:

Martínez et al. *Experimental investigation on sorption enhanced gasification (SEG) of biomass in a fluidized bed reactor for producing a tailored syngas*. Fuel, 2020, 259:116252

Martínez et al. *Optimised production of tailored syngas from municipal solid waste (MSW) by sorption-enhanced gasification.* Chemical Engineering Journal, 2020, accepted for publication (doi: 10.1016/j.cej.2020.126067).

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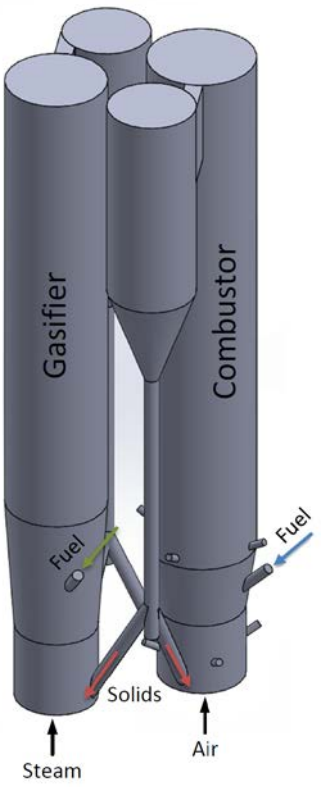
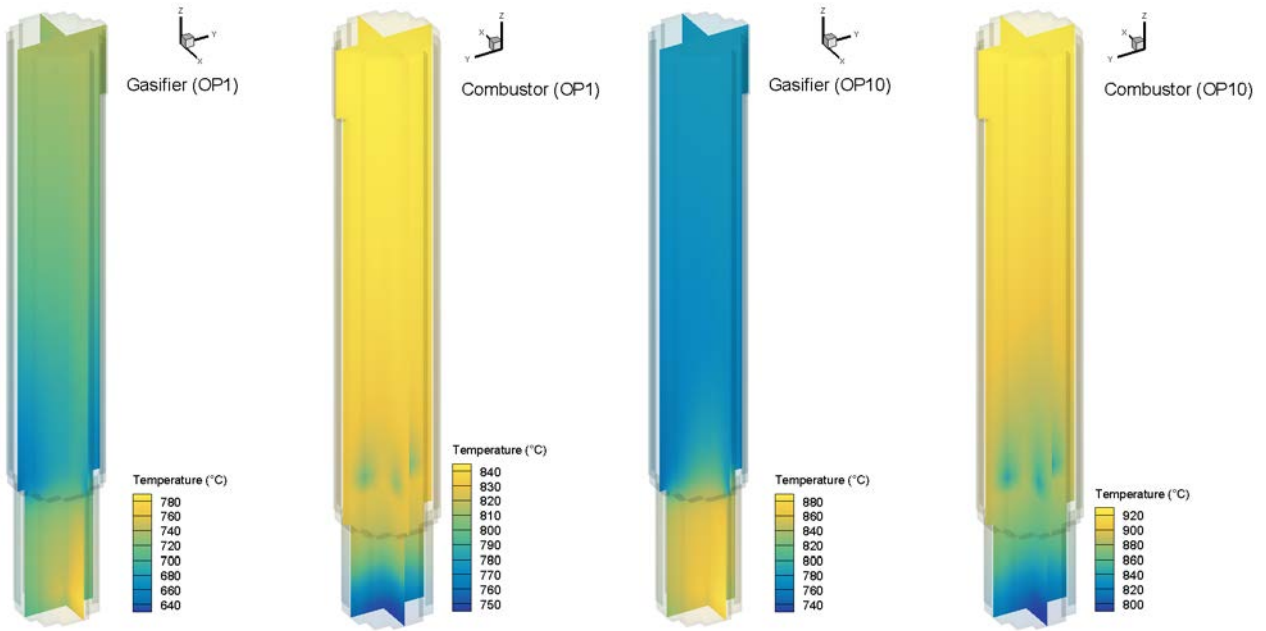
3D modelling of large scale SEG process (LUT)

LUT has continued activities with Sorption-Enhanced Gasification (SEG) modelling. Recently a new 3D model for connected SEG reactor system has been calibrated on data from University of Stuttgart and CSIC experiments. Model supported design work has been carried out for large scale SEG process in scale of 100MWth. As a result of the design work, reactors with height of 20m and inner diameter approximately 3m were found to be suitable for large scale SEG process. Detailed 3D simulations have been conducted to investigate SEG operation at two operation points. These operation points represents reference (OP1) and flexible operation (OP10), without and with hydrogen enhanced producer gas, respectively. In both operation points, gasifier producer gas ending up to DME synthesis after downstream process components has a composition expressed as Module equal to 2. Different operation points for the SEG process have been achieved by adjusting the gasifier temperature. The main control parameters for gasifier temperature are fuel ratio to reactors and solid circulation rate between the reactors. The following 3D simulation results for the SEG process illustrates estimated local conditions inside the reactors.



Dual fluidized bed design for 3D simulations.



Temperature profiles from 3D simulations for SEG operation without (OP1) and with (OP10) hydrogen enhancement downstream the gasifier.

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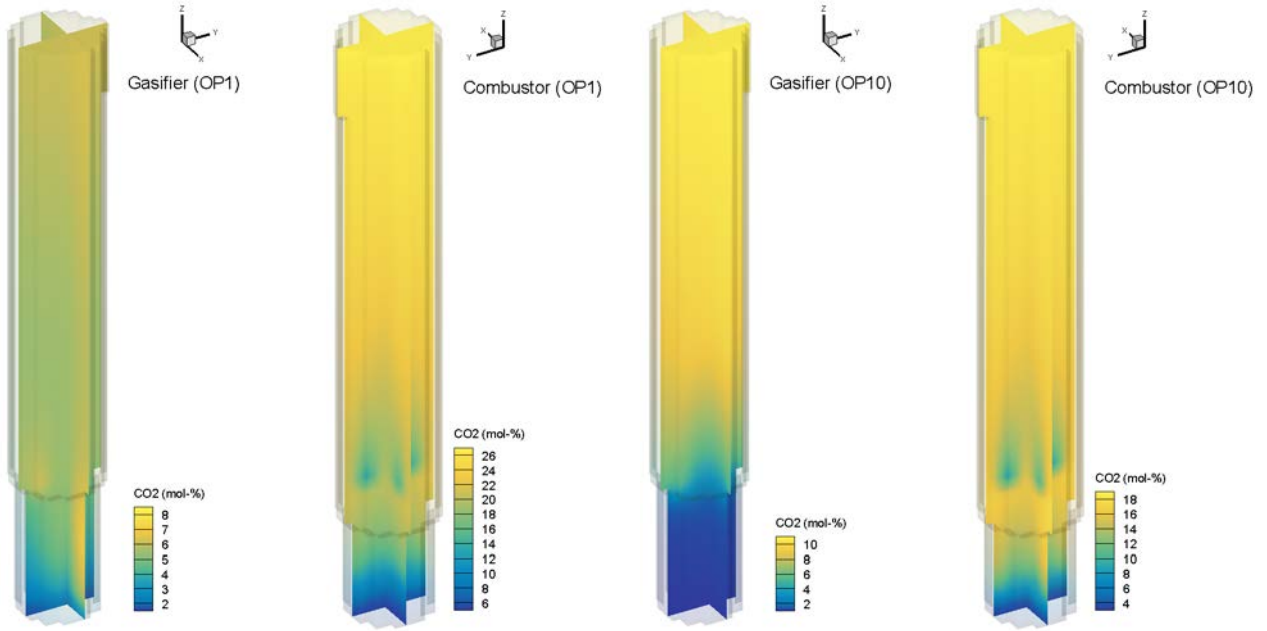
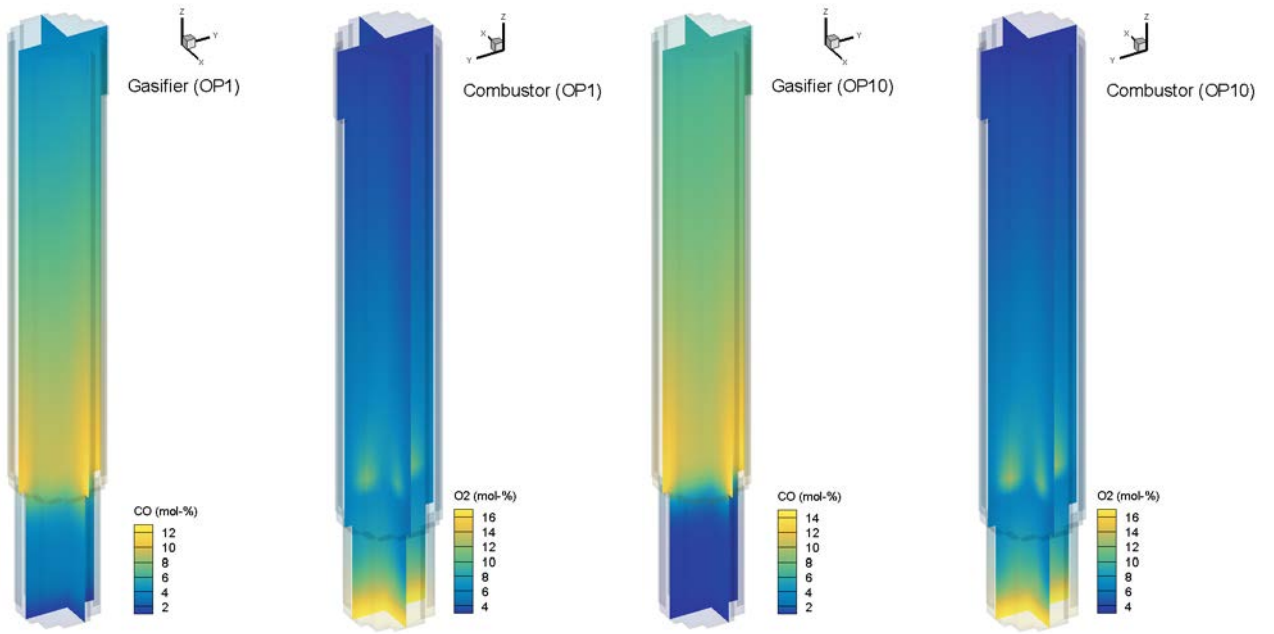


Simulated local CO_2 concentrations inside the SEG reactors. Operation points without (OP1) and with (OP10) hydrogen enhancement downstream the gasifier.



Simulated local CO concentrations inside the gasifier and local O_2 concentrations inside the combustor. Operation points without (OP1) and with (OP10) hydrogen enhancement downstream the gasifier.

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Scientific publications

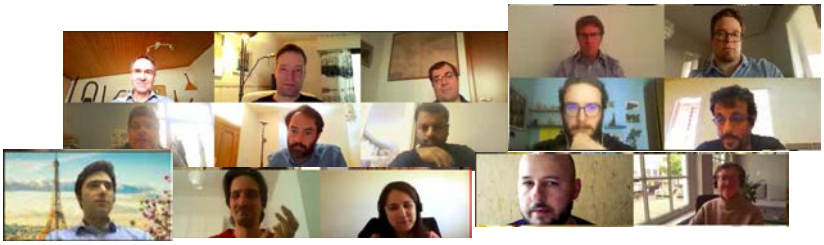
Simulation of a sorbent enhanced gasification pilot reactor and validation of reactor model (Antti Pitkäojaa, Jouni Ritvanen, Selina Hafner, Timo Hyppänen, Günter Scheffknecht, *Energy Conversion and Management, Volume 204, 2020*)

Abstract

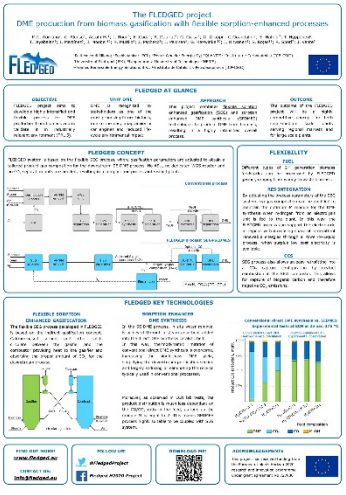
Sorption enhanced gasification (SEG) is a promising technology for production of a renewable feedstock gas for biofuel synthesis processes. The technology has been previously demonstrated at pilot scale. Scaling of the technology to an industrial size requires knowledge from governing phenomena. One-dimensional bubbling fluidized bed (BFB) reactor model was developed and validated against experimental data from 200kWth dual fluidized bed facility. Sub-models for biomass gasification, reactive bed material and fluidized bed hydrodynamics were incorporated into the model frame. The model gave satisfactory predictions for bed material conversion, temperature profiles and gas composition of the producer gas. The conducted validation improved understanding of bed material conversion, water–gas shift reaction and hydrodynamics and their role in SEG reactors. Further refinement and comprehensive validation of the model with additional data from the pilot is required. The knowledge from the comprehensive validation can be utilized in simulation of an industrial size reactor.

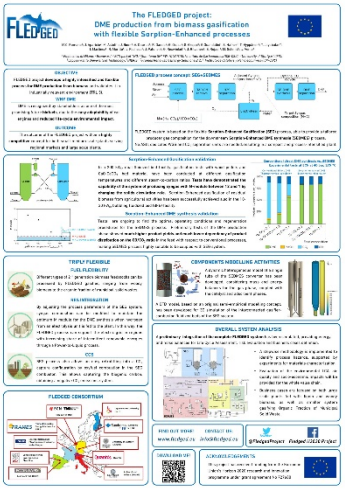
More in the scientific publications section of the website…

Due to the continuous changes in planned evens due to the current CoVid-19 situation, remain updated on FLEDGED project activities and on dissemination events in the project news and next events sections of our website.



Distanced, but work is still going on !!!





Project presentations, posters and deliverables

Posters, presentations and public deliverables of the project are available in the download section of the website.

An infographic and a video are also available for less experienced people about sorption-enhanced processes and biofuel synthesis.

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